Chapter 6. Bryce Canyon National Park

Introduction

Bryce Canyon National Park was added to the USDA system of National Monuments in 1923. The Monument became a National Park in 1928 when responsibility shifted to the National Park Service. Bryce Canyon National Park encompasses 14,508 ha, almost all federally owned (Figure 6-1). The Park lies in south central Utah along an escarpment of the Paunsaugunt Plateau and is therefore not a true canyon. Bryce Canyon is within Kane and Garfield Counties, and is bordered by the Dixie National Forest. The Park was originally established to protect the natural beauty of the area, specifically the naturally sculpted multicolored amphitheaters and rock "hoodoo" formations. The Presidential Proclamation that established the original Monument reads:

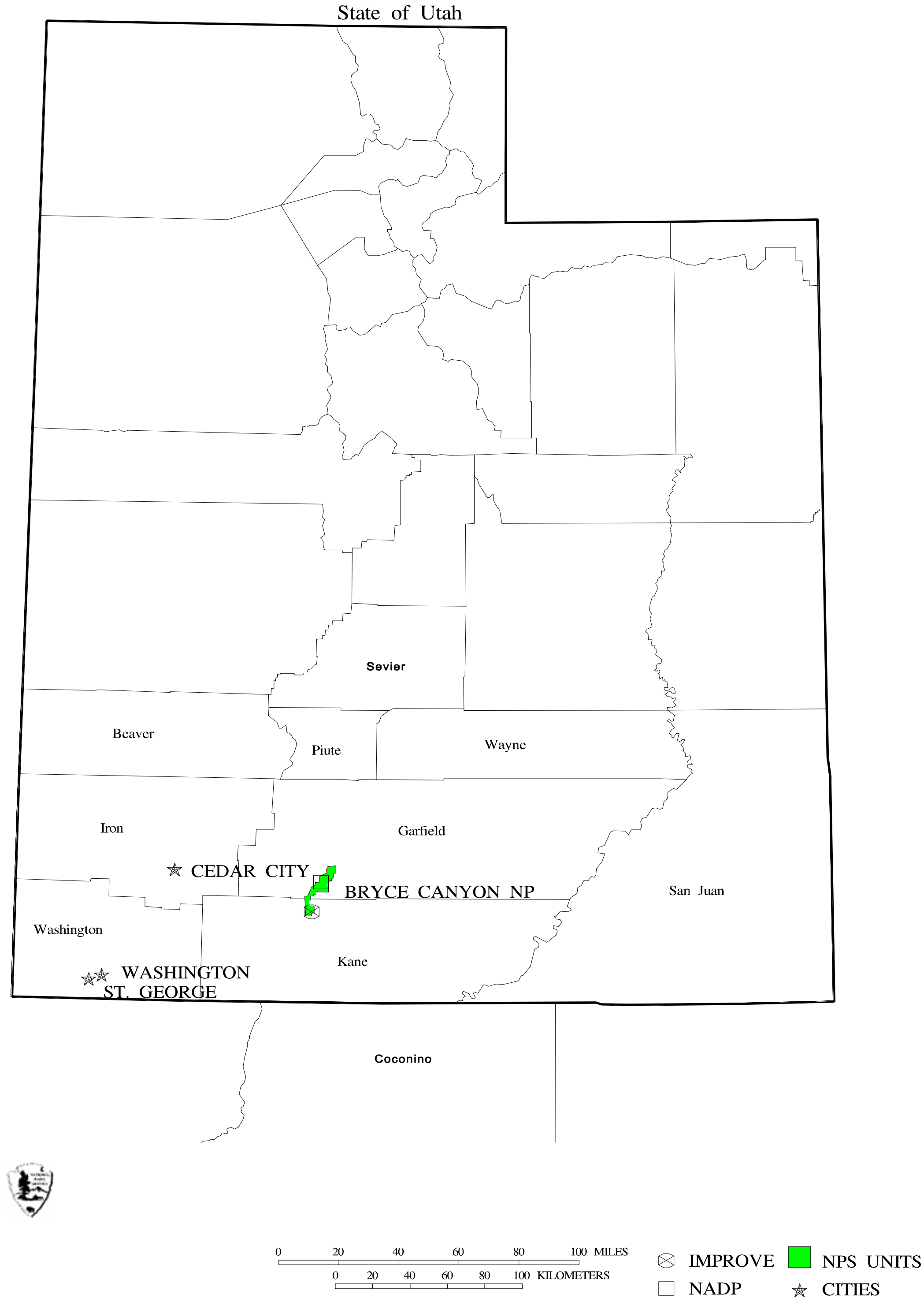
> "certain lands within the Powell National Forest in the State of Utah, known as Bryce Canyon, are of unusual scenic beauty, scientific interest and importance, and it appears that the public interest will be promoted by reserving these areas with as much land as may be necessary for the proper protection thereof as a National Monument".

Elevations in the park range from 2018 m at the north end of the Park to 2775 m at the south end of the Park.

Geology and Soils

The geology of Bryce Canyon National Park is relatively simple. The rocks from the Paleozoic and early Mesozoic Eras that underlie the region are not exposed within Bryce Canyon. During the Cretaceous Period, the region was gradually uplifted and the Cretaceous Seaway receded. Uplift processes raised the Rocky Mountains to the east and the Sevier Mountains to the west, developing a landlocked, lake-filled basin that accumulated sediments washed in from the surrounding mountains. The Claron Formation that comprises the majority of the escarpment at Bryce Canyon National Park developed from these lake deposits of silty limestone and mudstone. During the Oligocene and Miocene Epochs, the Colorado Plateau experienced extensive volcanism and uplift that resulted in faulting, intrusions and elevated rates of erosion. This period saw the formation of the Colorado River. Later, the Paria River developed and carved into the Paunsaugunt Plateau, producing the intricate gullies, canyons and "hoodoos" of Bryce Canyon (Chronic 1988).

Figure 6-1. Location of Bryce Canyon National Park.



Map produced by the National Park Service Air Resources Division

Sources: USGS 1:2,000,000 cdrom and NPS ARD GIS

Soils in the Park are largely derived from the Claron Formation and are therefore calcareous, with varying amounts of silt and clay and some sands cemented by carbonates, fine grained and usually easily eroded. Generally there is little topsoil and the fine textured soils drain poorly and hold water.

Climate

Bryce Canyon National Park averages about 390 mm of annual precipitation, with greater amounts at the higher southern end, and lower amounts at the lower, northern end. Temperature patterns show the opposite pattern, with cooler temperature at the higher elevations. At the Park headquarters, temperatures range from -8 ^{o}C in the winter to over 31 ^{o}C in the summer. Precipitation often comes in torrential downpours and in heavy snowfall; the winter snowpack typically exceeds 1.5 m.

Vegetation

The plateau is dominated by two major forest types. In the north end of Bryce Canyon National Park, from about 2,100 m to 2,600 m, ponderosa pine (*Pinus ponderosa*) plant communities dominate. Pines are interspersed with Rocky Mountain juniper (*Juniperus scopulorum*), Utah Juniper (*Juniperus osteosperma)* and a number of shrub and grass species that include green leaf manzanita (*Arctostaphylos patula*), antelope bitterbrush *(Purshia tridentata*), mountain lilac (*Ceanothus integerrimus*), Indian ricegrass (*Achnatherun hymenoides*), mutton grass (*Poa interior*) and mountain muhly (*Muhlenbergia montana*). Limber pine (*Pinus flexilis*) and bristlecone pine *(Pinus longaeva*) occupy some of the sunnier slopes and exposed ridges on the plateau rim. Below the rim, pinyon pine (*Pinus edulis*)/juniper (*Juniperus* spp.) communities occur, with sagebrush (*Artemisia* spp.) and rabbitbrush (*Chrysothamnus* spp.). Above 2,600 m, mixed-conifer communities dominate with Douglas-fir (*Pseudotsuga menzeisii*), white fir (*Abies concolor*), aspen (*Populus tremuloides*) and some blue spruce (*Picea pungens*). In the low light environment of the understory of these forests, common juniper (*Juniperus communis*), snowberry (*Symphoricarpos oreophilus*), creeping barberry (*Berberis repens*), and wild rose (*Rosa woodsii*) are encountered. Weedy exotics include Russian thistle (*Salsola tragus*), Russian knapweed (*Centaurea sp.*), crested wheatgrass (*Agropyron cristatum*), pigweed (*Cycloma sp.*), cheatgrass *(Bromus tectorum*), shepherd's purse (*Capella bursa-pastoralis*), bindweed (*Convolvulus arvensis*), horehound

(*Marrubium vulgare*), and English plantain *(Plantago lanceolata).* There are four NPS species of concern that occur near (but not documented within) Bryce Canyon: *Silene petersonii*, *Cryptantha ochroleuca*, *Penstemon bracteatus* and *Pediomelum pariense* (Threatened and Endangered Species Information Institute 1993). Complete species list for vascular flora are provided by NPFlora as well as by Buchanan and Graybosch (1981), Graybosch and Buchanan (1983), Hallsten and Roberts (1988), Spence and Buchanan (1993) and Peabody (1994). A list for lichen species is provided by Wetmore (1983).

Air Quality

Air quality monitoring for Bryce Canyon National Park consists of ozone concentrations (passive collector) for 1995 and 1996, NADP monitoring from 1985 to the present, sulfur dioxide measurements from 1988-1992 (except for 1990), and IMPROVE monitoring for visibility from 1988 to the present.

Emissions

Table 6-1 provides summaries for emissions of carbon monoxide (CO), ammonia (NH_3), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matter (PM), and sulfur oxides (SO_x) for 15 counties surrounding Bryce Canyon National Park. The emissions from Coconino County in northern Arizona are higher than from other counties in the area, with the vast majority of SO_x emissions coming from the Navajo Station of the Salt River Project. No information is available to relate these emissions to local air quality at Bryce Canyon National Park, or to apportion air quality impairment at Bryce Canyon to local and regional sources.

Table 6-1. Emissions (tons/day) for counties surrounding Bryce Canyon National Park (Radian 1994).

County	CO	NH_3	NO_x	VOC	PM	SO_x
Beaver, UT	14.9	0.7	1.7	31	142	0.3
Garfield, UT	13.7	0.6	1.5	63	253	0.2
Iron, UT	36.1	0.9	3.7	39	190	0.9

Kane, UT	14.9	0.3	1.6	44	114	0.2
Piute, UT	4.6	0.4	0.5	9	8	0.1
San Juan, UT	40.8	0.7	3.9	103	405	0.5
Sevier, UT	36.5	1.1	4.8	24	58	1.3
Washington, UT	63.7	0.6	6.5	34	189	0.9
Wayne, UT	6.3	0.6	0.7	30	122	0.1
Coconino, AZ	145.5	3.2	132.8	209	659	213.2

Air Pollutant Concentrations

The concentration of ozone for the summer of 1995 averaged about 46 ppb (based on weekly averages from passive collectors), with a peak weekly average of 53 ppb. The concentrations of SO_2 were far below any threshold of suggested sensitivity for any plants (Table 6-2).

Table 6-2. Concentrations (ppb) of SO_2 (24-hour averages) for Bryce Canyon National Park, measured by IMPROVE filter samplers.

Year	SO_2
1988	
Mean	0.0
Max	0.3
1989	
Mean	0.1
Max	0.5
1991	
Mean	0.2
Max	0.8
1992	
Mean	0.1
Max	0.5

Visibility

Bryce Canyon National Park is part of the IMPROVE Monitoring Network. The aerosol sampler began operation in March 1988 and the camera began operation in January 1979. The data from this IMPROVE site have been summarized to characterize the full range of visibility conditions for the period March 1988 through February 1994. The camera is located at Rainbow Point, and the particulate sampler near the Visitors Center. The seasons used throughout this data presentation are: spring = March, April, and May; summer = June, July, and August; autumn = September, October, and November; and winter = December, January, and February.

Aerosol Data

Aerosol sampler data are used to reconstruct the atmospheric extinction coefficient (b_{ext}) from experimentally determined extinction efficiencies of certain species. The reconstructed extinction data are used as background conditions to run plume and regional haze models. These data are also used in the analysis of visibility trends and conditions.

Table 6-3 provides a summary of the reconstructed extinction from the aerosol sampler data, presented as seasonal and annual 50th and 90th percentile standard visual range for Bryce Canyon National Park. The 50th percentile means that visual range is this high or lower 50% of the time. This is an average 50th percentile for each season. The 90th percentile means that the visual range is this high or lower 90% of the time. This is an average 90th percentile for each season.

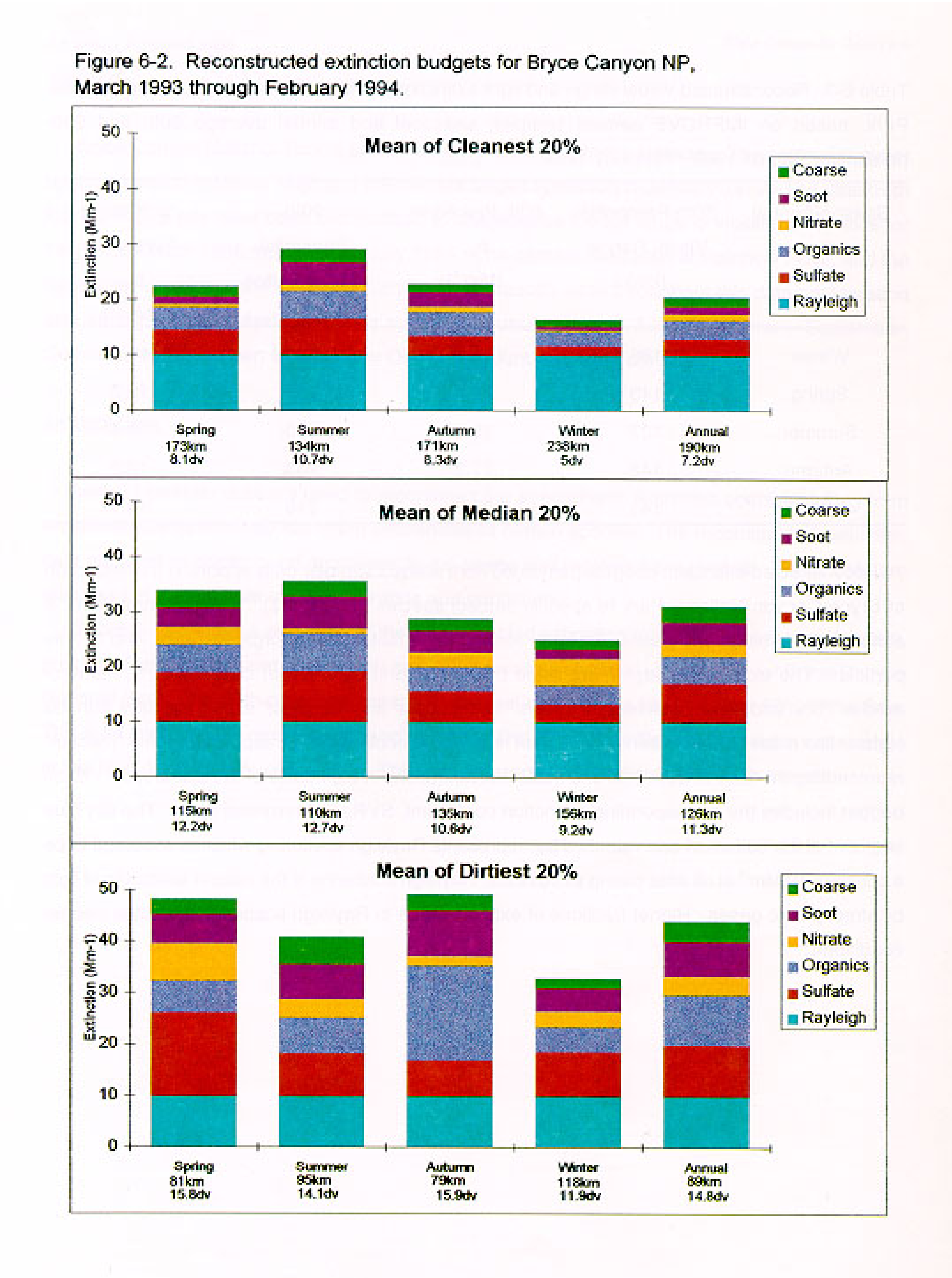
Table 6-3. Reconstructed visual range and light extinction coefficients for Bryce Canyon National Park, based on IMPROVE aerosol sampler, seasonal and annual average 50th and 90th percentiles, March 1988 - February 1994.

Season/Annual	50th Percentile Visual Range (km)	50th Percentile b_{ext} (Mm^{-1})	90th Percentile Visual Range (km)	90th Percentile b_{ext} (Mm^{-1})
Winter	186	21.0	244	16.0
Spring	143	27.4	203	19.2

Summer	127	30.7	160	24.4
Autumn	143	27.3	203	19.2
Annual	141	27.7	216	18.1

Reconstructed extinction budgets generated from aerosol sampler data apportion the extinction at Bryce Canyon National Park to specific aerosol species (Figure 6-2). Visibility impairment is attributed to atmospheric gases (Rayleigh scattering), sulfate, nitrate, organics, soot, and coarse particles. The extinction budgets are listed by season and by mean of cleanest 20%, mean of median 20%, and mean of dirtiest 20% days. The "dirtiest" and "cleanest" signify the days with the highest fine mass concentrations and lowest fine mass concentrations respectively, with "median" representing the 20% of days with fine mass concentrations in the middle of the distribution. Each budget includes the corresponding extinction coefficient, SVR, and haziness in dv. The sky blue segment at the bottom of each stacked bar represents Rayleigh scattering which is assumed to be a constant 10 Mm^{-1} at all sites during all seasons. Rayleigh scattering is the natural scattering of light by atmospheric gases. Higher fractions of extinction due to Rayleigh scattering indicates cleaner conditions.

Figure 6-2. Reconstructed extinction budgets for Bryce Canyon National Park, March 1993 through February 1994.



Atmospheric light extinction at Bryce Canyon National Park, like many rural western areas, results primarily from aerosols of sulfate, organic compounds, and soot. In pre-industrial times, visibility would vary with patterns in weather, with winds (and the effects of winds on coarse particles), and with fires. We have no information on how the distribution of visibility conditions at present differs from the profile under "natural" conditions, but the cleanest 20% of the days probably approach natural conditions (GCVTC 1996).

Photographs

Three photos are provided to represent the range of visibility conditions at Bryce Canyon National Park (Figure 6-3). The photos were chosen to provide a feel for the range of visibility conditions possible and to help relate the SVR/extinction/haziness numbers to what the observer sees.

Visibility Projections

The Grand Canyon Visibility Transport Commission (GCVTC 1996) projected likely visibility for Bryce Canyon National Park through 2040, and the major species responsible for visibility impairment. Reduced emissions from utilities were projected to reduce light extinction by approximately 1 Mm^{-1}. Light extinction caused by vehicle emissions was projected to decline until approximately 2005, and then increase through 2040 (Figures 6-4, 6-5). The dirtiest days have more than twice the visibility impairment, and the bulk of the change results from human- related sources. There is some concern that the modeling completed by the GCVTC may not adequately represent the relative contribution of near and far away sources.

Figure 6-3. Photographs representing visibility conditions at Bryce Canyon National Park.

Figure 6-3. Photographs representing visibility conditions at Bryce Canyon National Park.

Bryce Canyon National Park
on a "clear" day.

Representative Conditions:

Visual Range:	290 - 380 km
b_{ext}:	13 - 10 Mm^{-1}
Haziness:	3 - 0 dv

Bryce Canyon National Park
on a "average" day.

Representative Conditions:

Visual Range:	230 - 270 km
b_{ext}:	17 - 14 Mm^{-1}
Haziness:	5 - 4 dv

Bryce Canyon National Park
on a "dirty" day.

Representative Conditions:

Visual Range:	100 - 130 km
b_{ext}:	39 - 30 Mm^{-1}
Haziness:	14 - 11 dv

Figure 6-4. Projected “baseline” light extinction for Bryce Canyon National Park (GCVTC 1996).

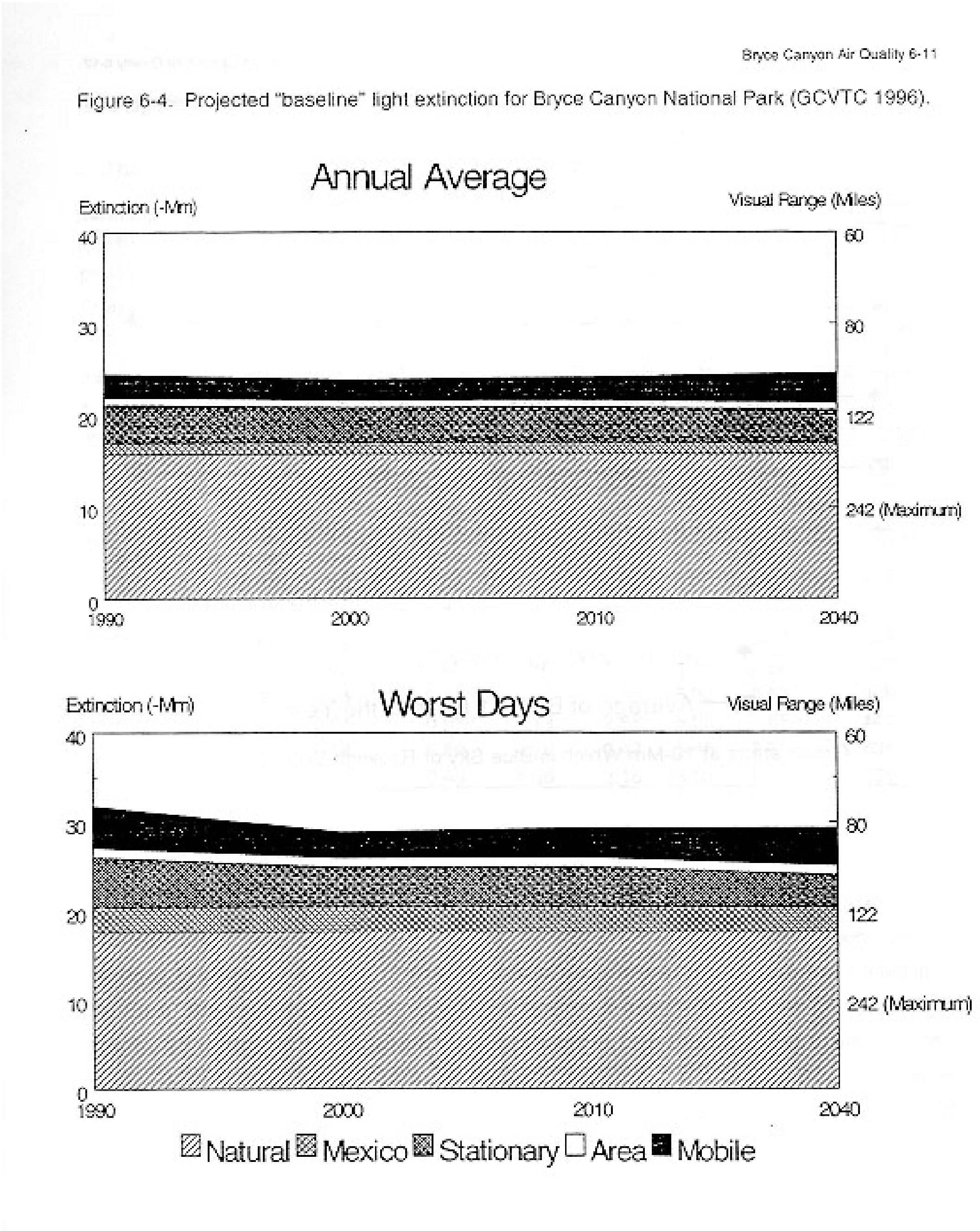


Figure 6-5. Projected “baseline” visibility for Bryce Canyon National Park for good, average, and poor conditions (GCVTC 1996).

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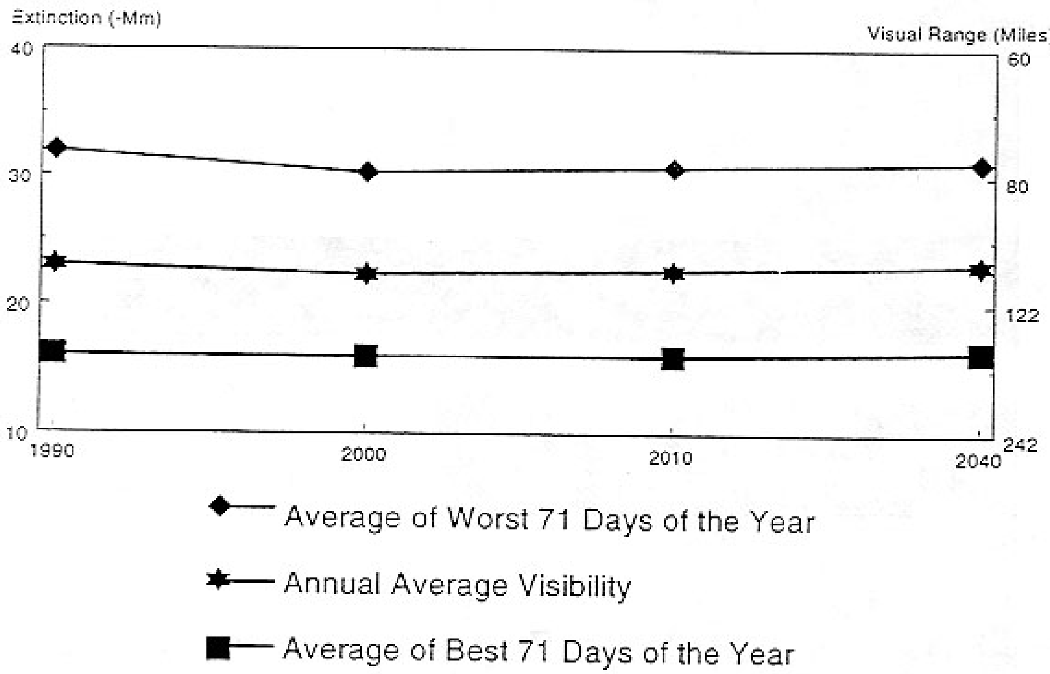
Figure 6-5. Projected “baseline” visibility for Bryce Canyon National Park for good, average, and poor conditions (GCVTC 1996).



Graph starts at 10-Mm Which is Blue Sky or Rayleigh Extinction.

Atmospheric Deposition

The rates of atmospheric deposition for Bryce Canyon National Park are quite low (Table 6-4). Precipitation pH averages about 5.3. Deposition of N averages about 1 kg N ha^{-1} yr^{-1}, which is slightly higher than the rate of S deposition. The deposition of N and S showed no trend during this period. There is no evidence that such low levels of deposition pose any threat to plants (see Chapter 2).

Table 6-4. Atmospheric deposition for Bryce Canyon National Park (NADP). Note the values for N and S compounds include the whole molecule and not just the N or S atoms.

	Concentration (mg/L)			Deposition (kg ha^{-1} yr^{-1})				Conductivity	Precipitation
year	NH_4	NO_3	SO_4	NH_4	NO_3	SO_4	pH	(μS/mm)	(mm/yr)
1985	0.07	0.64	0.71	0.27	2.46	2.72	5.19	0.75	384
1986	0.05	0.54	0.58	0.17	1.84	1.97	5.12	0.61	340
1987	0.09	0.67	0.70	0.39	2.93	3.07	5.07	0.72	438
1988	0.07	0.88	0.78	0.22	2.77	2.45	5.17	0.74	314
1989	0.18	1.06	0.76	0.44	2.58	1.85	5.56	0.87	244
1990	0.20	0.95	0.68	0.69	3.30	2.36	5.18	0.86	347
1991	0.14	0.90	0.64	0.51	3.31	2.35	5.32	0.67	368
1992	0.13	0.70	0.64	0.58	3.13	2.86	5.22	0.65	447
1993	0.14	0.75	0.54	0.89	4.76	3.43	5.45	0.58	634
1994	0.14	0.88	0.67	0.45	2.86	2.18	5.01	0.81	325

Sensitivity of Plants

No signs of air pollution injury have been reported for vegetation in or near Bryce Canyon National Park. Only a few of the Park's species have been tested under controlled conditions for sensitivity to pollutants, and none of these tests included genotypes representative of the plants in the Park. Based on the ozone concentrations required to affect very sensitive plants (such as aspen), we expect that current ozone exposures could be high enough to affect some species. Current levels of ozone are probably too low to affect the conifers, and levels of SO_2 are far below any demonstrated threshold of sensitivity for any plants. In the absence of empirical evidence of any effects, no substantial problem is likely.

Water Quality and Aquatic Organisms

Aquatic Invertebrates

The eastern slope of Bryce Canyon National Park forms a part of the headwaters of the Paria River, a tributary of the Colorado River. The current macroinvertebrate species list for Bryce Canyon includes 13 Orders, with the largest number of species falling into these Orders (Dorr and Weiss 1994):

Ephemeroptera (Mayflies, including *Baetis* spp.),
Plecoptera (Stoneflies),
Coleoptera (Beetles), and
Diptera (True flies, including Chironimids).

Two sites (Mossy Cave and Yellow Creek Swamp) had the highest number of species represented.

Amphibians

An amphibian species list for the park includes the tiger salamander (*Ambystoma tigrinum*), Great Basin spadefoot toad *(Scaphiopus intermontanus)*, and leopard frog (*Rana pipiens*) (Hallows 1982). Specimens have been found in a variety of habitats in the Park, and in livestock ponds and beaver ponds outside the Park. Historic information on amphibian species can be found in Tanner (1930). Surveys in 1929 yielded tiger salamanders and spadefoot toads. These amphibians appear to be reproducing in seeps and springs since there are few permanent water courses in the park.

Water Quality Conclusions

No evidence indicates any threat to water quality or aquatic organisms from air pollution in Bryce

Canyon National Park.

Recommendations for Future Monitoring and Research

General recommendations for NPS Class I areas of the Colorado Plateau are presented in Chapter 14, and many of these apply to Bryce Canyon. Continued monitoring of visibility should remain a high priority. Bryce Canyon is higher in elevation than several other NPS areas in southeastern Utah, and inversion layers in winter that affect other parks may not reach the elevation of Bryce; differences in visibility between Bryce and Canyonlands, for example, can provide useful insights to the role of winter inversions in regional air quality (C. Bowman, personal communication). We also recommend:

- measurements of ozone (continuous or passive) be maintained.

We found no information on surface water quality in Bryce Canyon NP. Seeps and springs, and some ephemeral pools are the habitat for both vertebrate and invertebrate fauna. Given the geological substrates, acidification of aquatic systems in the Park is unlikely. However, we recommend:

- baseline water chemical data be collected in habitats where macroinvertebrates and amphibian larvae occur. The suite of measurements could be as simple as pH, ANC, and conductance.

Park Summary

Bryce Canyon National Park is located in an area where the best visibility in the lower 48 United States occurs. However, current levels of pollution in southern Utah can produce haze and obscure the important vistas of the park and surrounding area. Any increase in aerosols will undoubtedly impair visibility further; substantial reductions in aerosols would be needed to restore pristine conditions at Bryce Canyon National Park.

Little information has been collected on air pollution effects on the Park's biota. No sign of air pollution impacts on plant or animal species has been reported; ozone concentrations are high enough that some impact is possible for sensitive plants, but SO_2 concentrations are too low to affect plants.

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